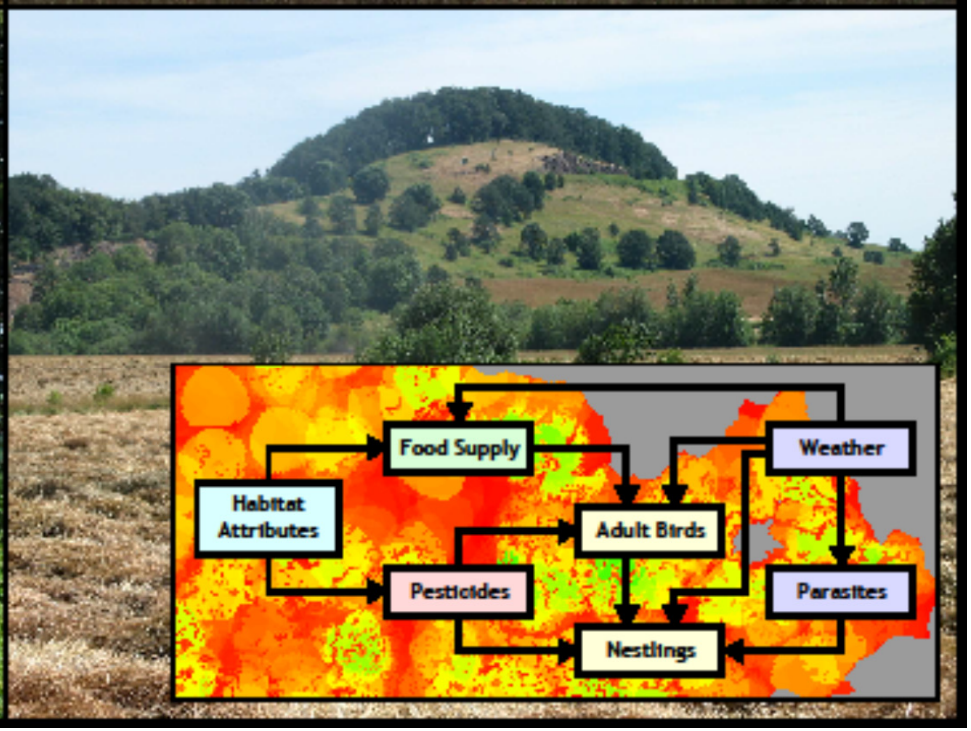
Using HexSim to Simulate Complex Species, Landscape, and Stressor Interactions

Nathan Schumaker, Allen Brookes, Chad Wilsey
and the Subsequent Speakers



OOS 20 - Recent Advances in Individual-Based Population Modeling with Applications to Conservation and Management

- **Focus.** Modern simulation models and their use in conservation biology and landscape ecology.
- **Why This Focus?** Models are increasingly required to forecast plant and animal responses to future conditions and disturbance patterns.
- **Today's Talks.** This introduction, plus nine presentations illustrating a wide range of applications of the *HexSim* model.

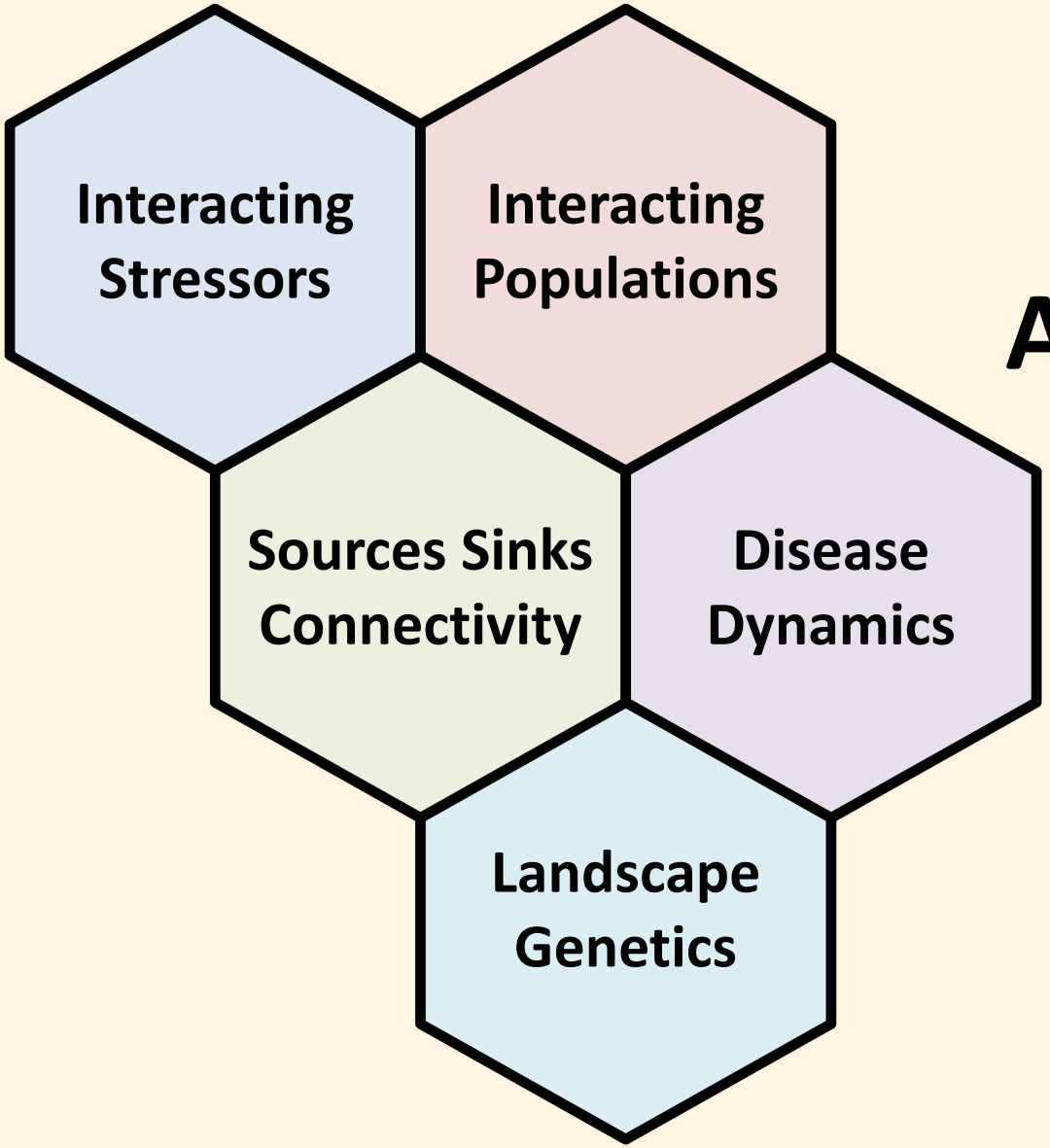
HexSim Past, Present, Future

- **Past.** HexSim grew out of the PATCH model. Work on PATCH dates back to 1995. HexSim development began in 2007.
- **Present.** HexSim 2.0 debuted in February 2011. Significant enhancements and corrections have since been made. Version 3.0 (in development) will include aquatic populations.
- **Future.** Case studies and outreach. Subsequent enhancements will reflect user-defined needs!

Why HexSim ?

- **It's a free, modern, and generic multi-species, multi-stressor, modeling framework.**
- **It's spatially-explicit, individual-based, and each individual may possess unique groups of traits.**
- **Simulations range from simple to complex, and can capture population and stressor interactions.**

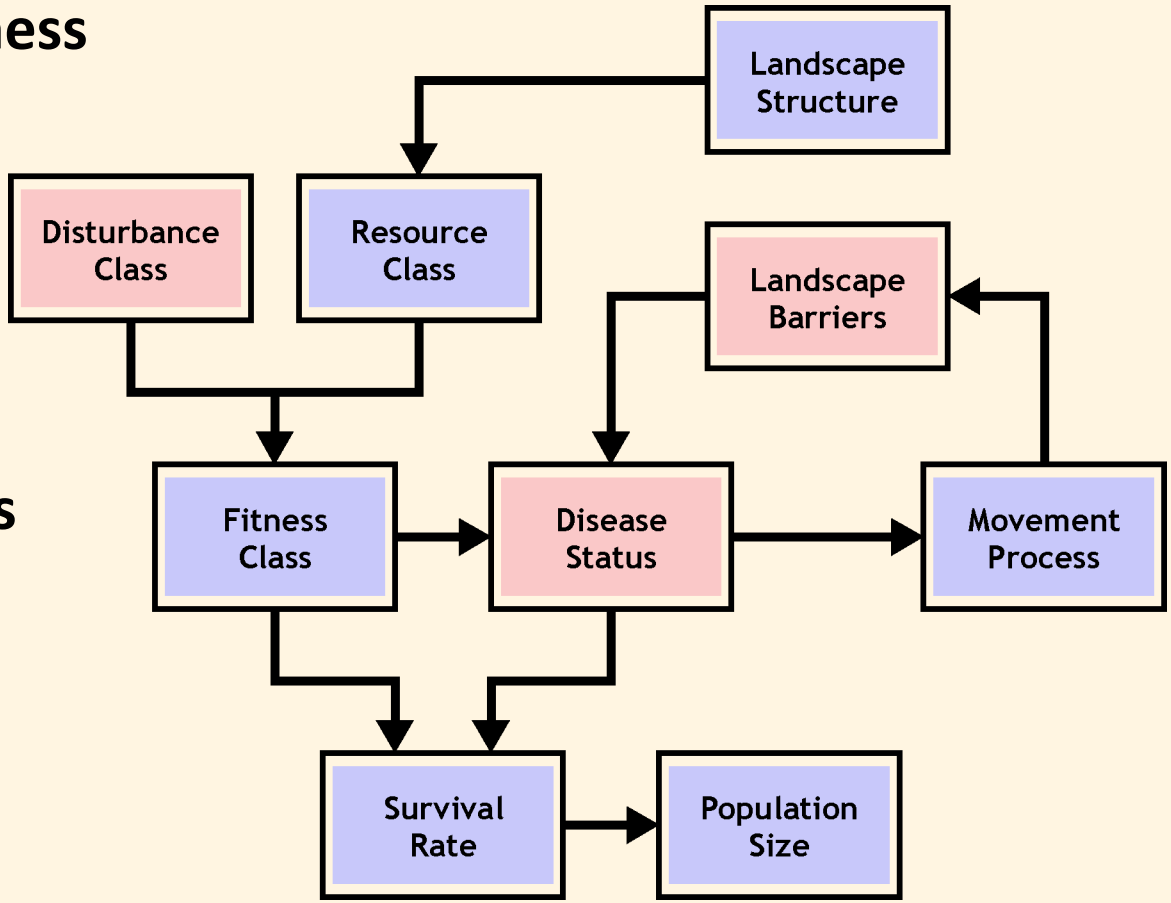
www.hexsim.net



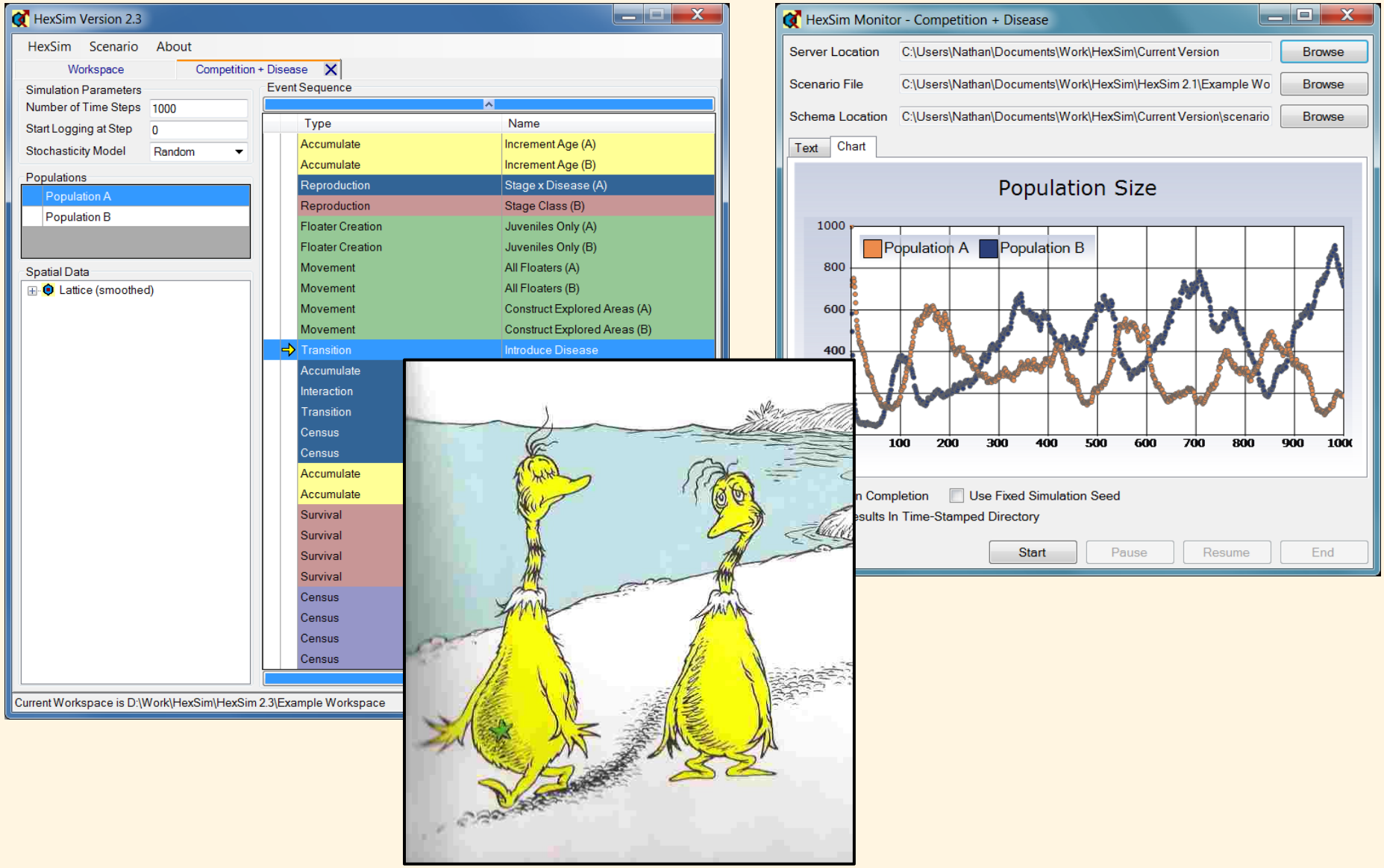
Five Example HexSim Applications

Interacting Stressors

- Landscape structure and population size together limit resource acquisition
- Resource acquisition and disturbance class together control fitness
- Fitness and disease control vital rates
- Roads impact the movement process
- Movement mediates disease spread



Interacting Populations

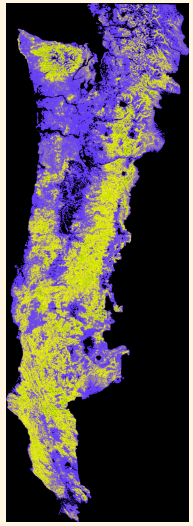


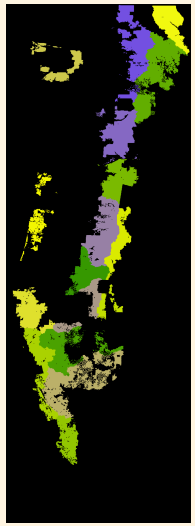
Sources, Sinks, Connectivity

- **Multiple spatial sampling schemes can be used simultaneously to quantify the landscape's source-sink and connectivity properties.**
- **The sampling schemes are completely independent of, and have absolutely no impact on the simulated population dynamics.**
- **The source-sink and connectivity metrics that result factor in species and stressor interactions, the effects of movement barriers, etc.**

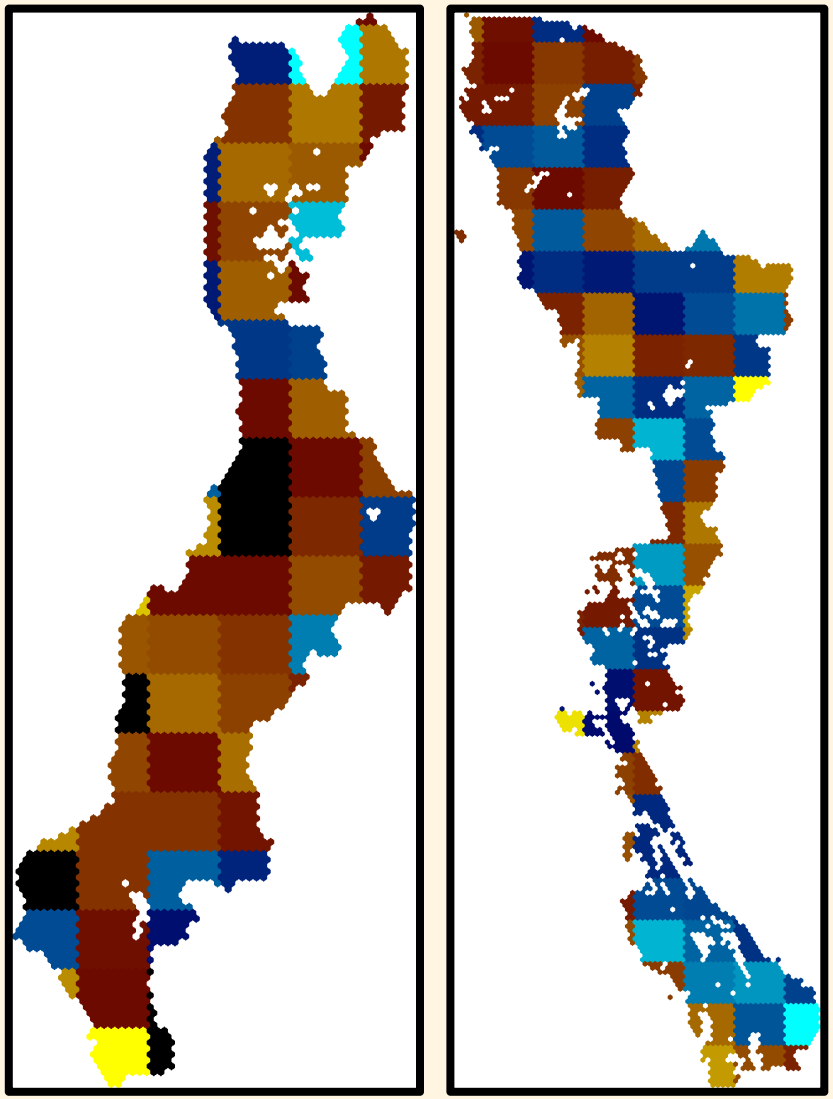
Example from US FWS Spotted Owl Model

Deschutes NF





Six Rivers NF



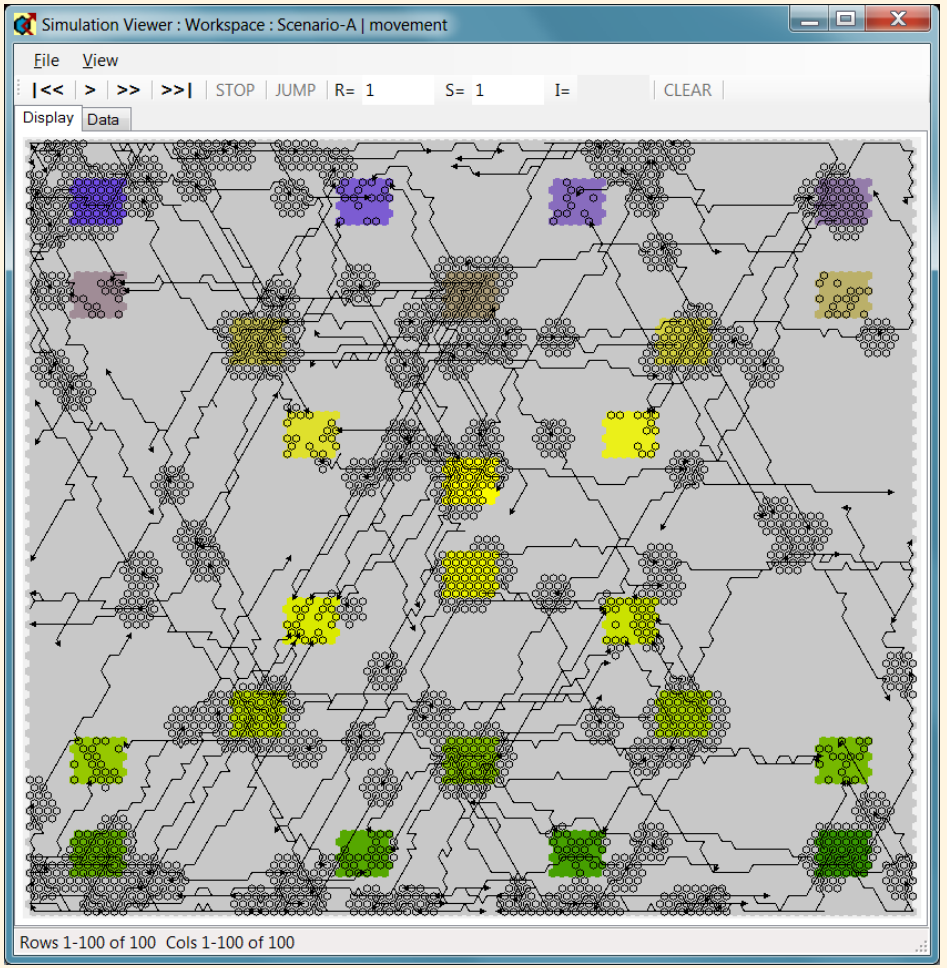
Sources and Sinks in HexSim

National Forest	Type	Percent of Worst Sink Or Best Source
Deschutes	Sink	100.0
Winema	Sink	44.8
Siuslaw	Sink	5.5
Okanogan	Sink	1.7
Olympic	Sink	0.4
Mount Baker	Source	0.1
Gifford-Pinchot	Source	3.1
Wenatchee	Source	9.0
Mount Hood	Source	17.4
Siskiyou	Source	18.3
Willamette	Source	42.0
Mendocino	Source	42.2
Klamath	Source	42.9
Rogue River	Source	56.6
Shasta-Trinity	Source	66.4
Umpqua	Source	69.3
Six Rivers	Source	100.0

Connectivity in HexSim

For each sampling scheme, HexSim will:

- Track the flux of individuals moving between locations, incorporating survival and reproduction into the rates
- Construct a projection matrix that can also be used to estimate λ
- Does not record paths used to move between locations (but see Carroll / CAT talk)



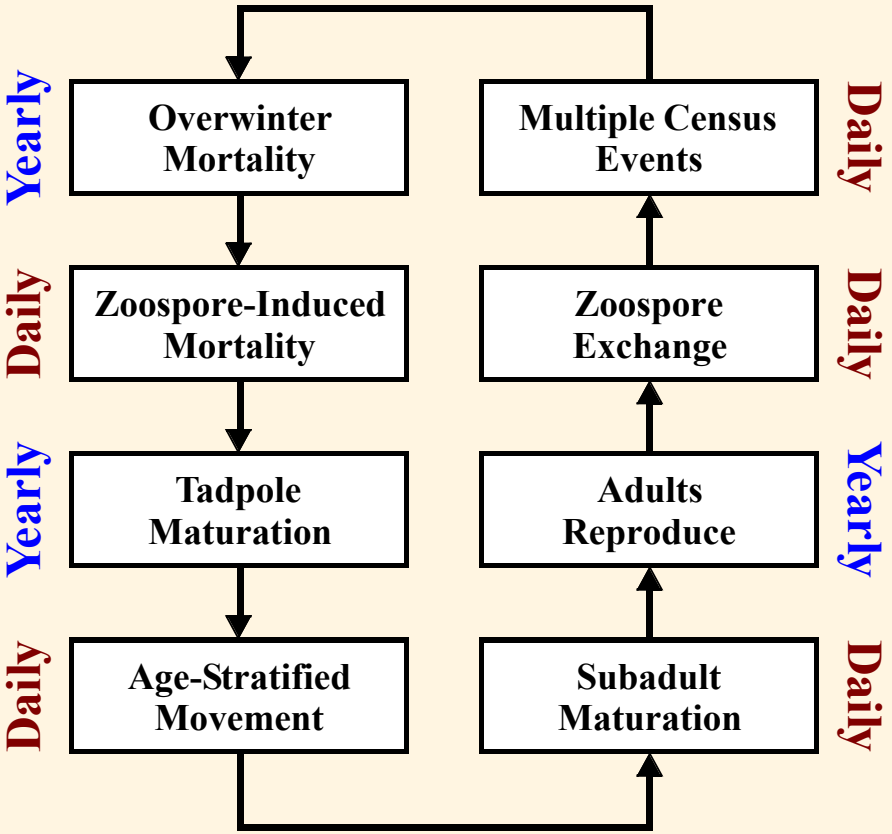
National Forest Connectivity

Example from US FWS Spotted Owl Model

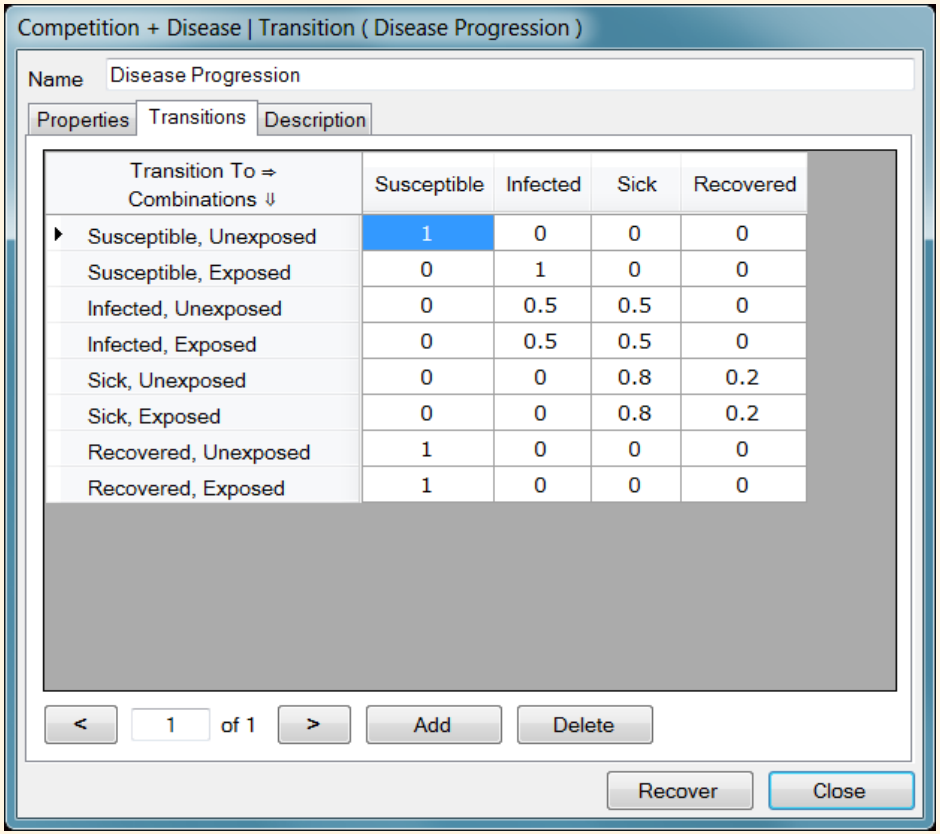
	Mount Baker	Gifford Pinchot	Willamette	Rogue River	Shasta-Trinity	Olympic	Siskiyou	Okanogan	Suislaw	Deschutes	Winema	Six Rivers	Mendocino	Mount Hood	Wenatchee	Klamath	Umpqua
Mount Baker	0.9110	0.0001	--	--	--	--	--	0.0083	--	--	--	--	--	--	0.0153	--	--
Gifford Pinchot	0.0004	0.9461	--	--	--	--	--	--	--	--	--	--	--	0.0016	0.0056	--	--
Willamette	--	--	0.9501	0.0000	--	--	--	--	0.0001	0.0381	--	--	--	0.0190	--	--	0.0176
Rogue River	--	--	0.0000	0.8532	--	--	0.0087	--	--	0.0000	0.0560	--	--	--	--	0.0175	0.0199
Shasta-Trinity	--	--	--	0.0000	0.9157	--	--	--	--	--	--	0.0325	0.0130	--	--	0.0115	--
Olympic	--	--	--	--	--	0.7083	--	--	--	--	--	--	--	--	--	--	--
Siskiyou	--	--	--	0.0066	--	--	0.9122	--	--	--	--	0.0026	--	--	--	0.0046	--
Okanogan	0.0001	--	--	--	--	--	--	0.8738	--	--	--	--	--	--	0.0002	--	--
Suislaw	--	--	0.0000	--	--	--	0.0000	--	0.8692	--	--	--	--	0.0000	--	--	--
Deschutes	--	--	0.0052	0.0001	--	--	--	--	--	0.8989	--	--	--	0.0000	--	--	0.0005
Winema	--	--	--	0.0158	--	--	--	--	--	0.0000	0.8823	--	--	--	--	0.0000	0.0000
Six Rivers	--	--	--	0.0000	0.0234	--	0.0060	--	--	--	--	0.9000	0.0082	--	--	0.0276	--
Mendocino	--	--	--	--	0.0062	--	--	--	--	--	--	0.0042	0.9420	--	--	--	--
Mount Hood	--	0.0023	0.0059	--	--	--	--	--	--	0.0001	--	--	--	0.9487	--	--	--
Wenatchee	0.0399	0.0041	--	--	--	--	--	0.0094	--	--	--	--	--	--	0.9441	--	--
Klamath	--	--	--	0.0269	0.0063	--	0.0090	--	--	--	0.0001	0.0214	--	--	--	0.9011	--
Umpqua	--	--	0.0230	0.0309	--	--	--	--	--	0.0074	0.0001	--	--	--	--	--	0.9252

Disease Dynamics

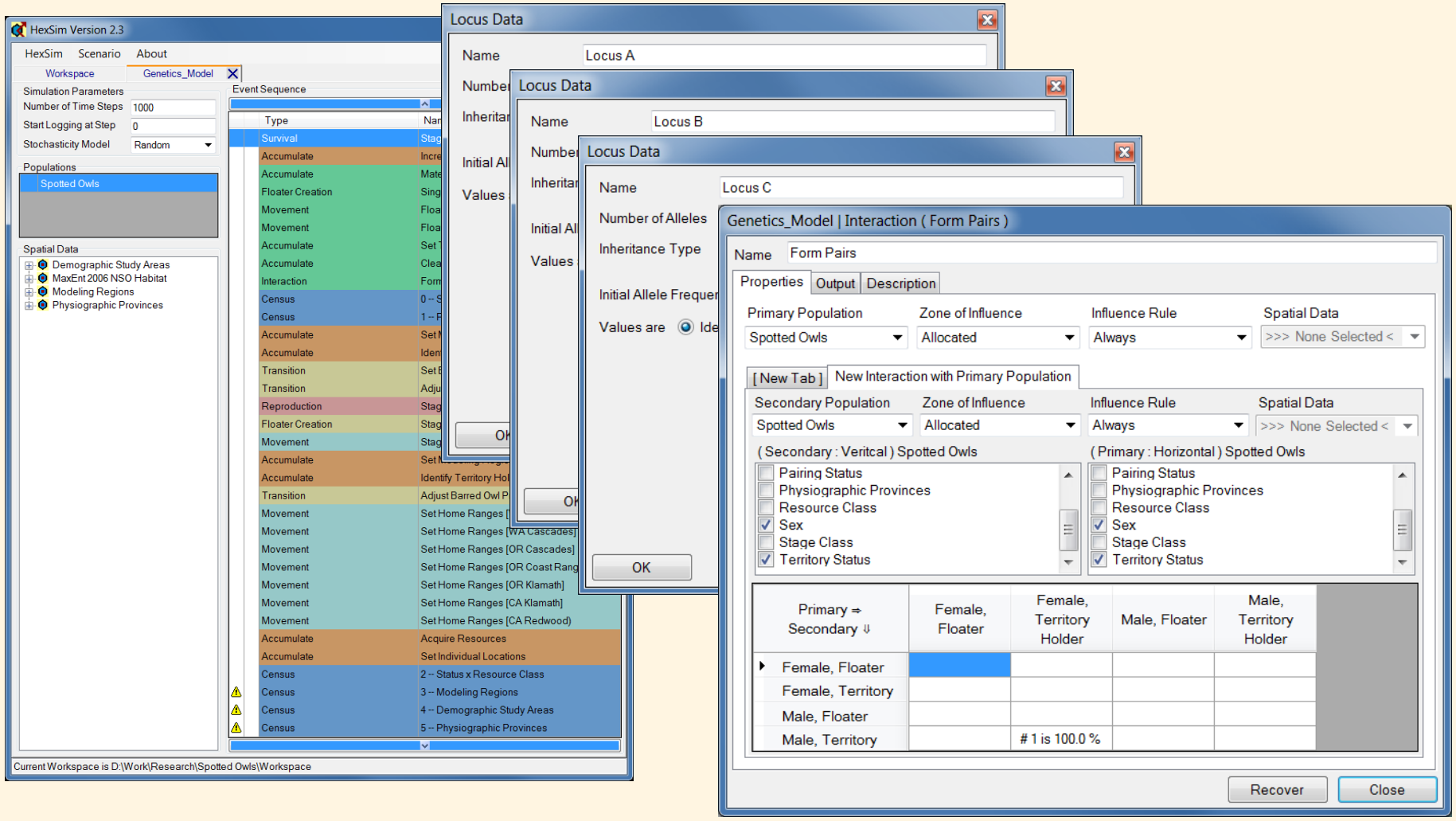
Environmentally-Mediated Transmission



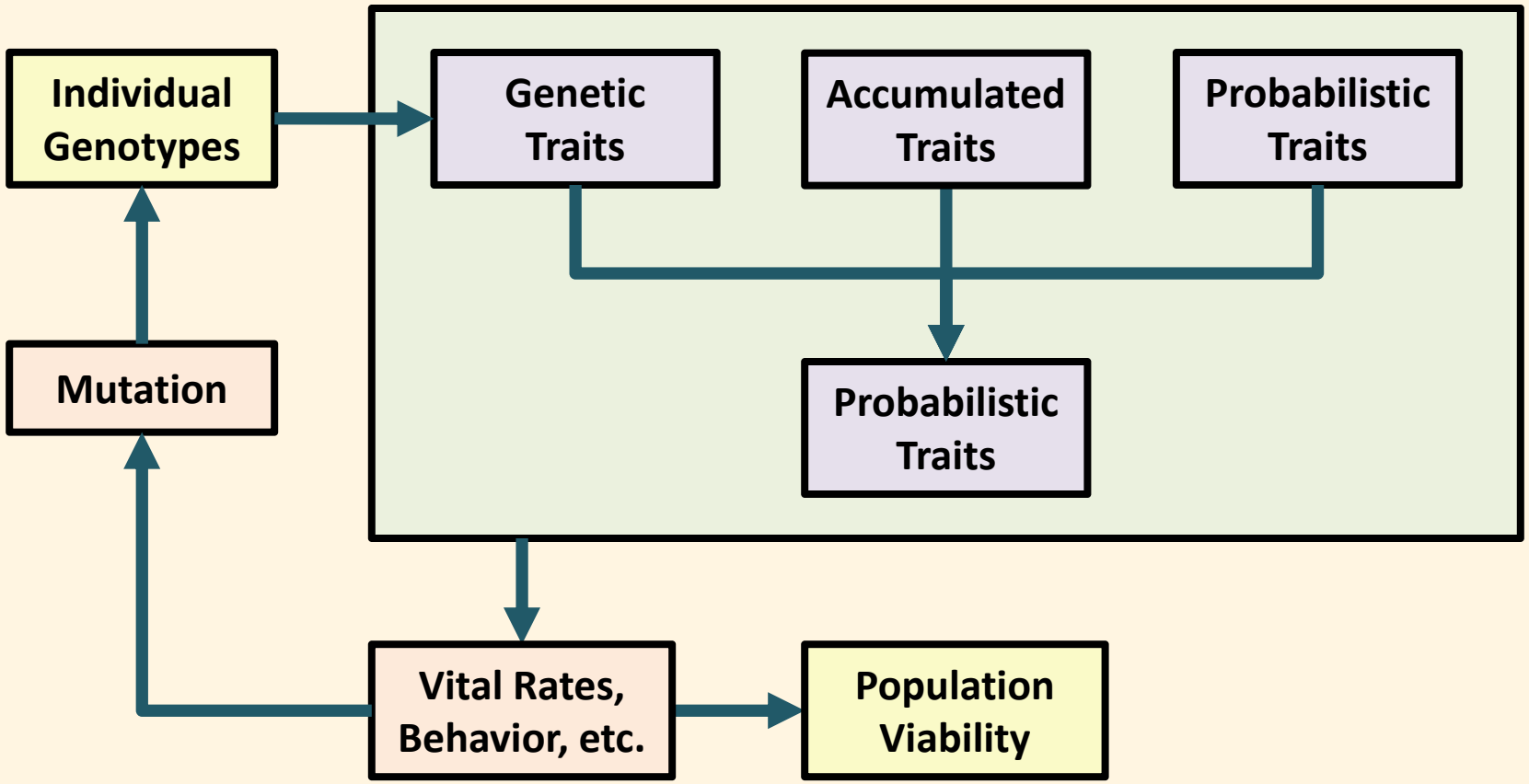
Direct Transmission

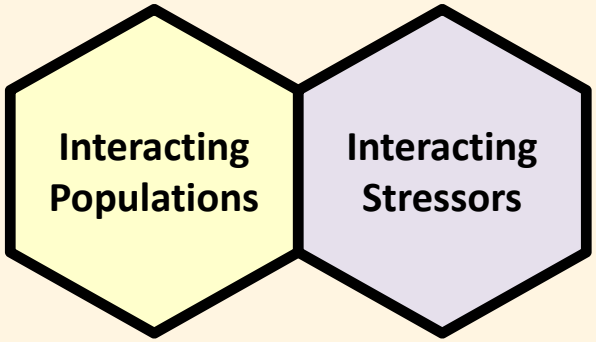


Landscape Genetics in HexSim



Works With Both Neutral and Adaptive Alleles





Speaker: Peter Singleton

Spotted Owl – Barred Owl Competition

Spotted Owl

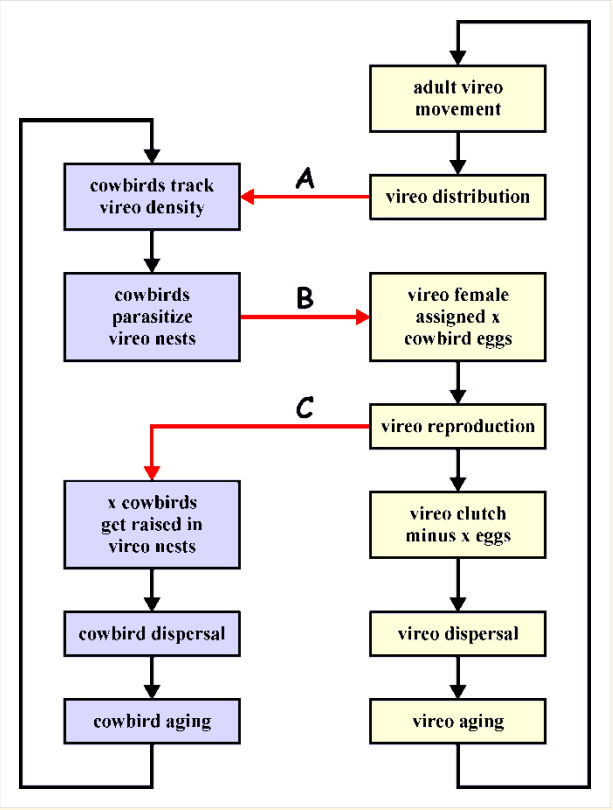
Barred Owl

Interacting Populations

Interacting Stressors

Speaker: Chad Wilsey

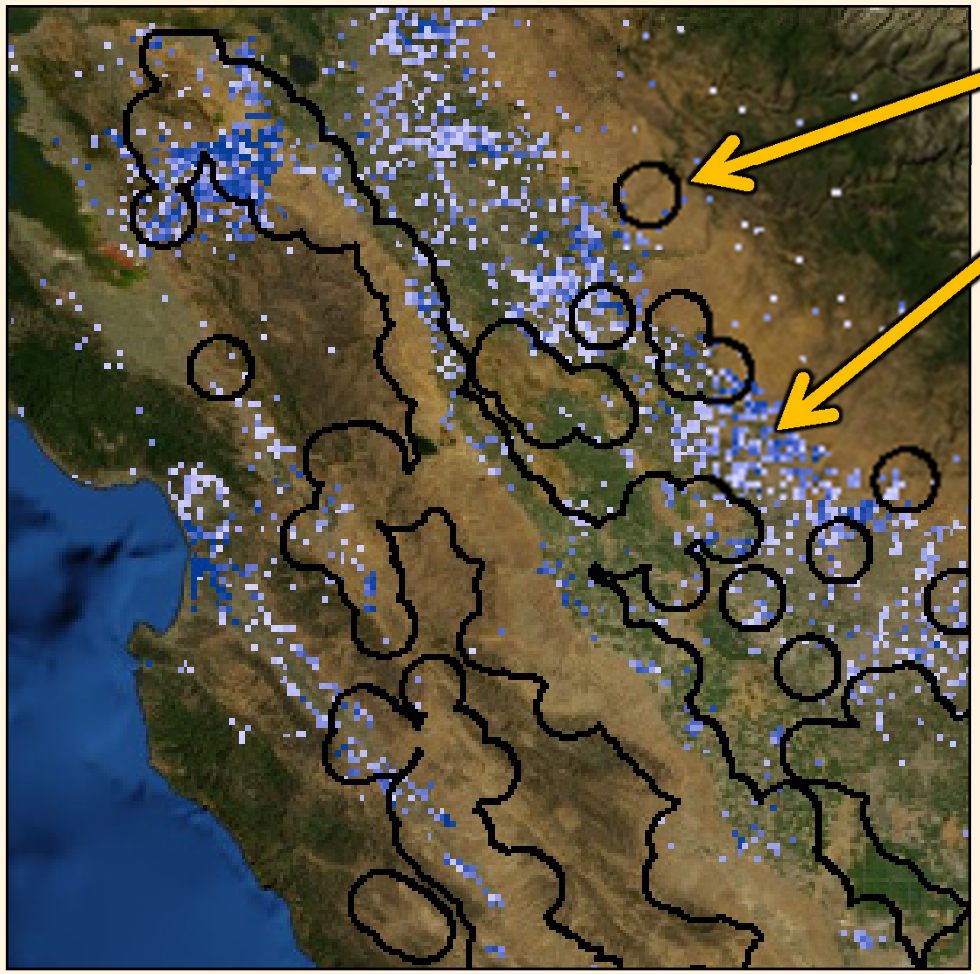
Black-capped Vireo – Cowbird Interactions



Interacting Stressors

Speaker: Theresa Nogeire

Kit Fox Responses to Multiple Stressors



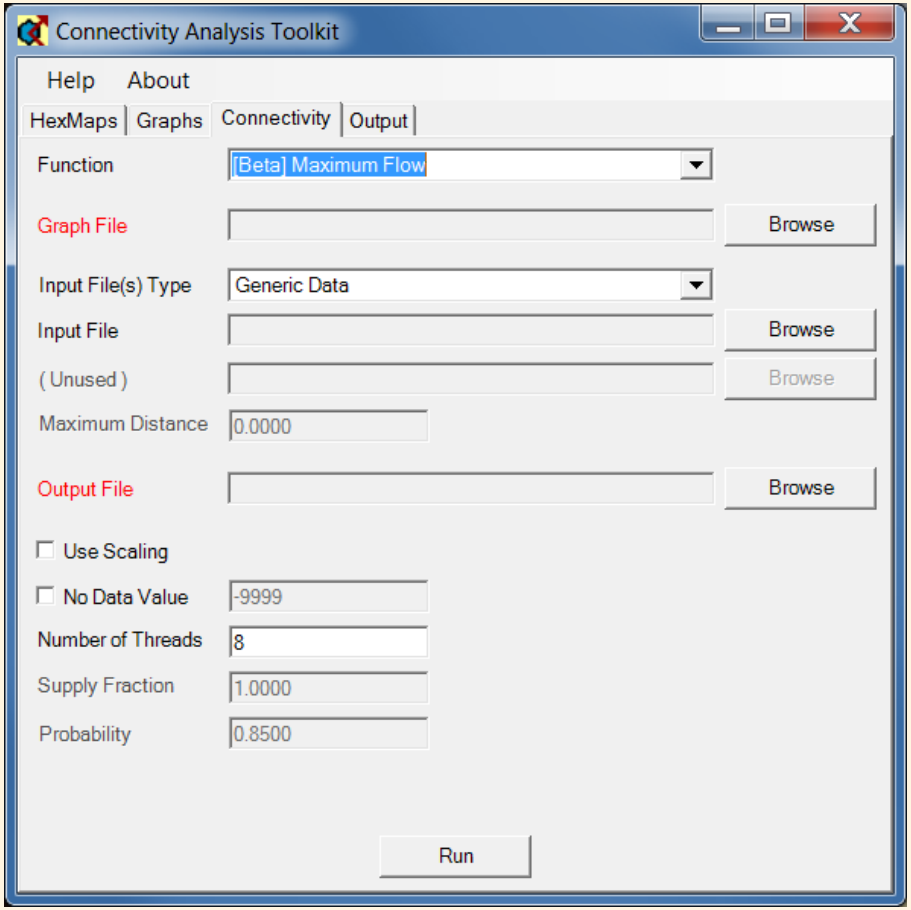
Kit Fox Range

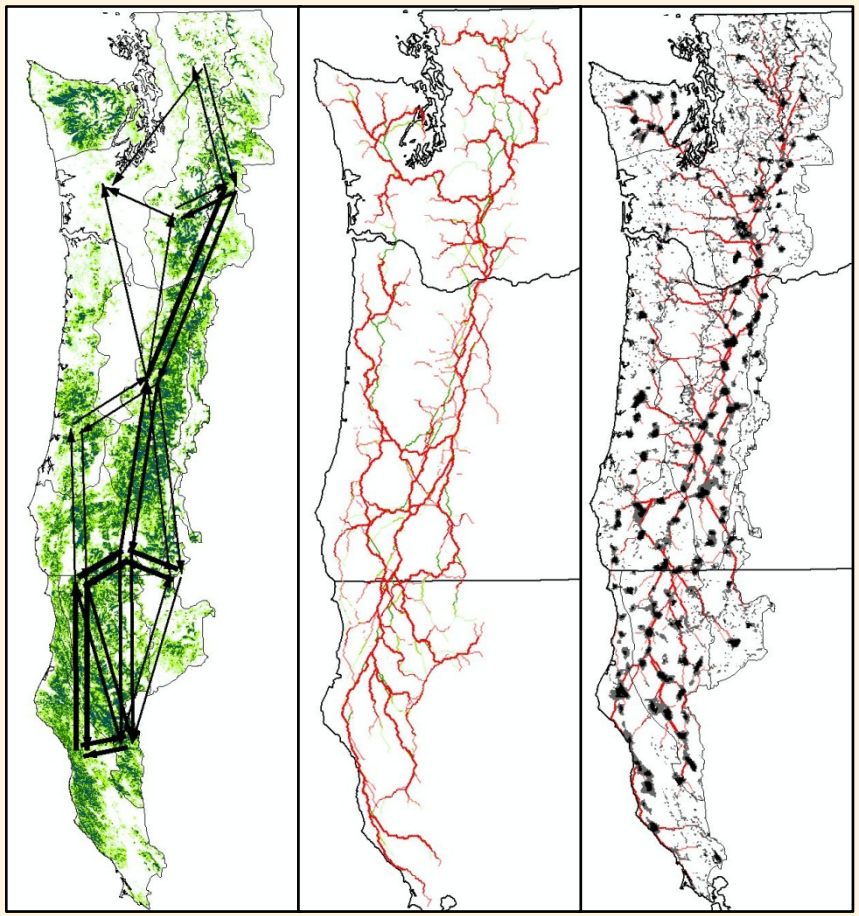
Rodenticides

Sources Sinks Connectivity

Speaker: Carlos Carroll

The Connectivity Analysis Toolkit (CAT)



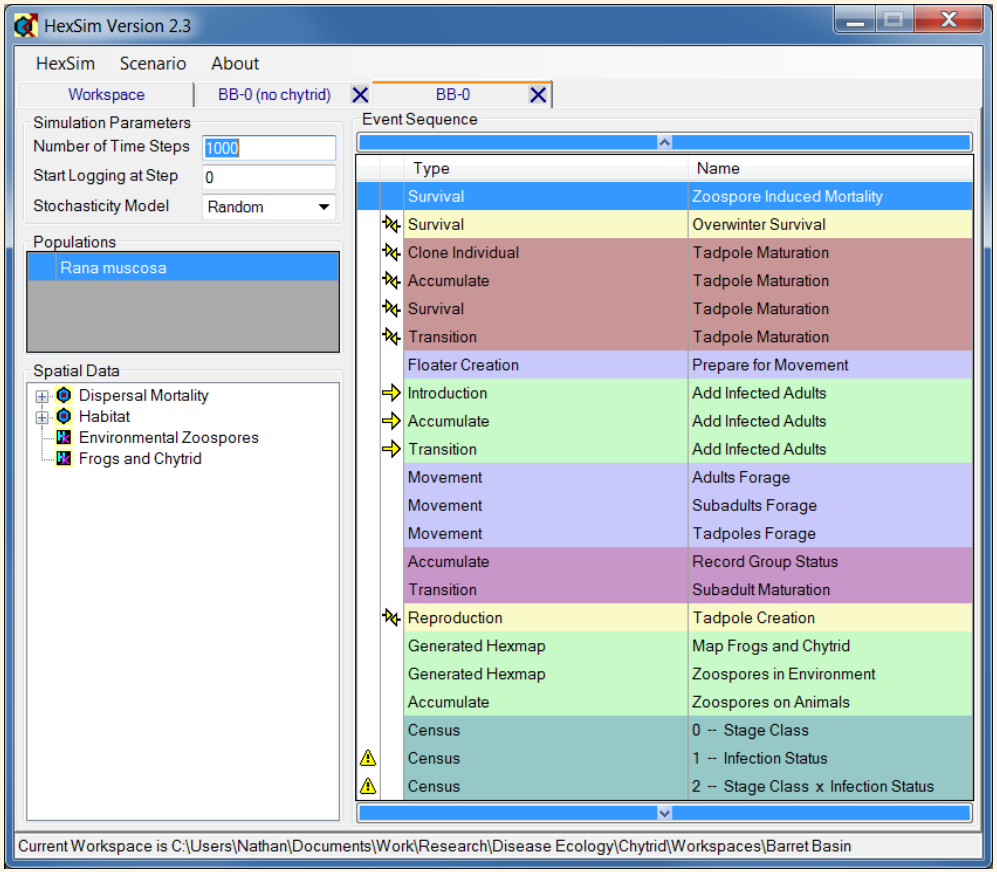


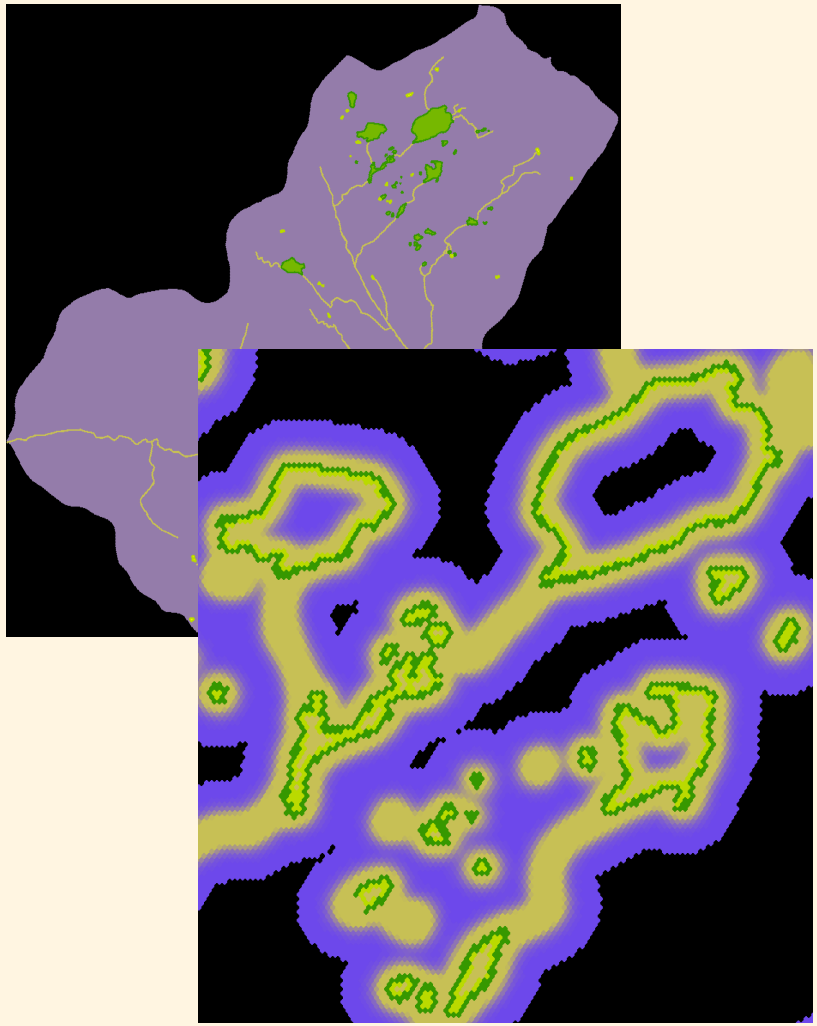
Interacting Stressors

Disease Dynamics

Speaker: Gisselle Yang Xie

Mountain Yellow-Legged Frogs and the Chytrid Fungus





Interacting Stressors

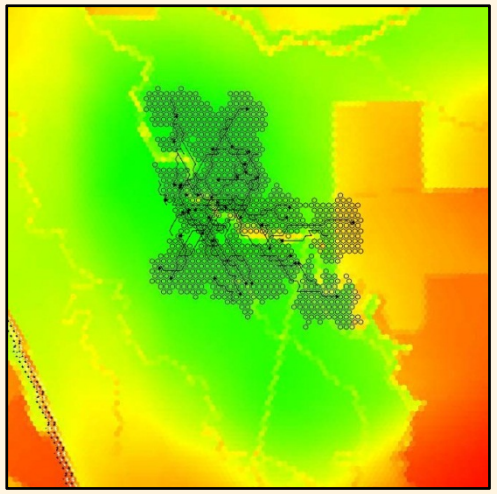
Speaker: Michael Tuma

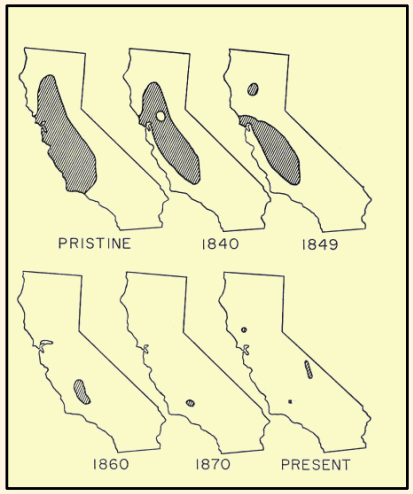
Desert Tortoise Population Dynamics

Interacting Stressors

Speaker: Patrick Huber

Tule Elk Reintroduction Strategies



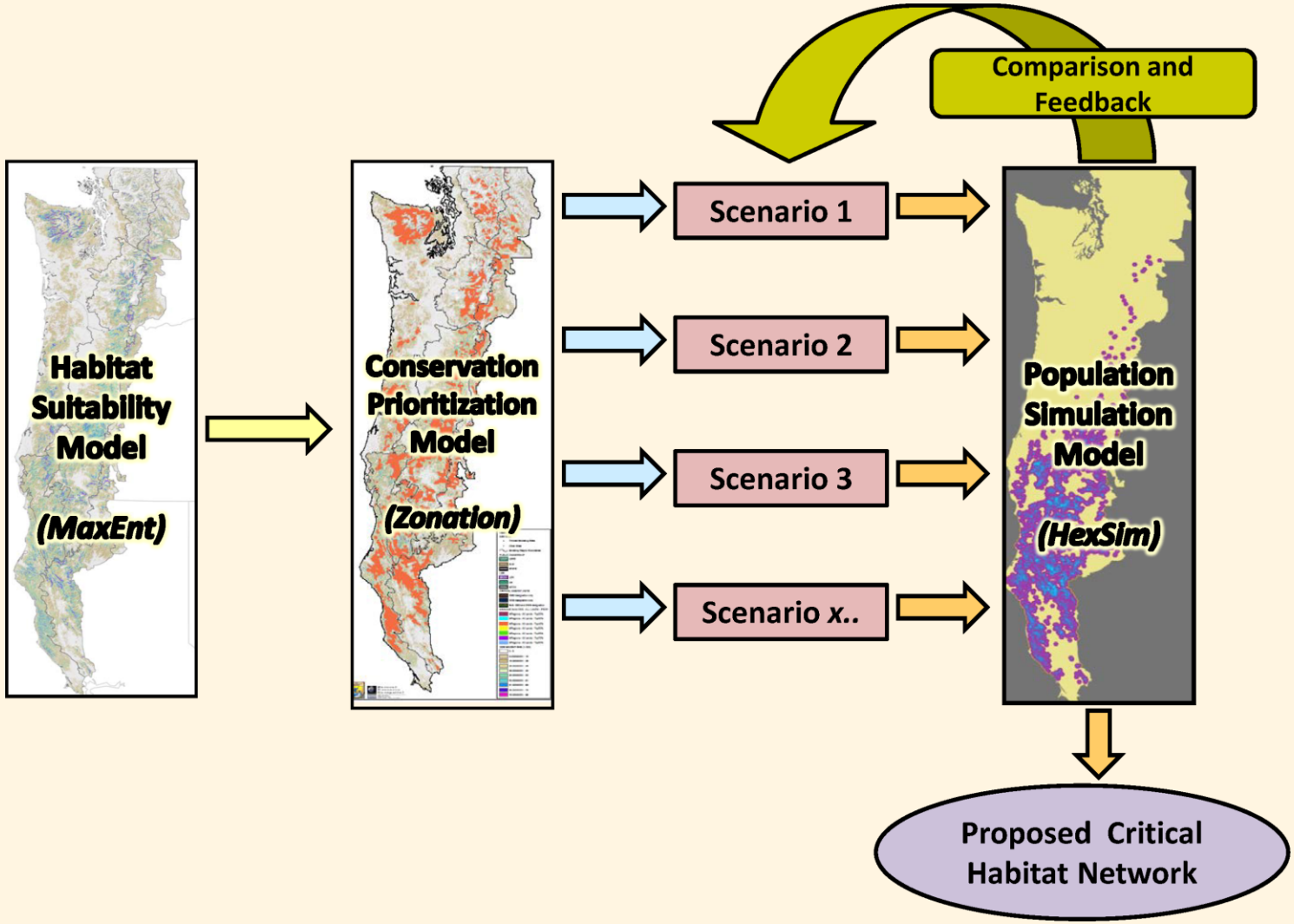


Interacting Populations

Interacting Stressors

Speaker: Jeffrey Dunk

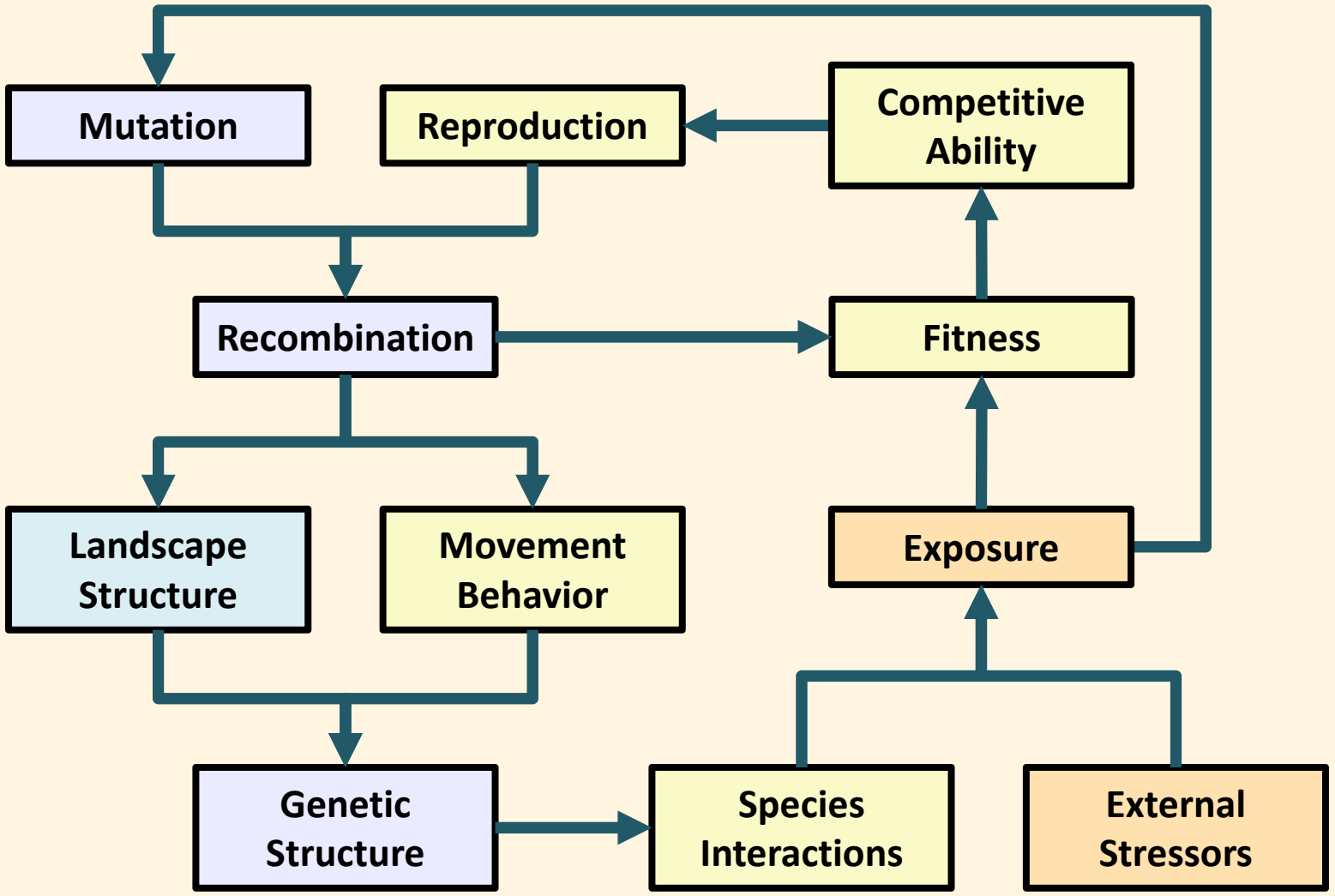
Spotted Owl Conservation



Landscape Genetics

Speaker: Jennifer Day

Adding Realism to Landscape Genetics



Acknowledgements

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- Carlos Carroll, Chris Jordan, and David Olszyk provided invaluable support at key times.
- The US EPA supported Schumaker, Brookes, and Djang. SERDP (grant number SI-1541) supported Brookes, and Lawler.
- We are indebted to many users who happily documented HexSim's (previous) shortcomings!